CLAIMS

1. A locating system for determining the location and orientation of an invasive medical instrument relative to a reference frame, comprising:

a plurality of field generators which generate known, distinguishable fields in response to drive signals;

a plurality of sensors situated in the invasive medical instrument proximate the distal end thereof which generate sensor signals in response to said fields; and

a signal processor which has an input for a plurality of signals corresponding to said drive signals and said sensor signals and which computes the three location coordinates and three orientation coordinates of a portion of the invasive medical instrument, responsive to said drive and sensor signals.

2. The locating system according to claim 1 wherein one of the plurality of field generators or sensors comprises three distinguishable, non-overlapping, generators or sensors.

3. The locating system of claim 1 wherein said plurality of field generators comprises three distinguishable, non-overlapping, generators and said plurality of sensors comprises three distinguishable, non-overlapping sensors.

4. The locating system of any of claims 1-3 wherein each sensor comprises a coil.

5. The locating system of claim 4 wherein said plurality of coils have axes which intersect within a coil.

6. The locating system of claim 4 or claim 5 wherein said plurality of coils comprises three coils and wherein said coils have axes which do not all intersect in a point.

7. The locating system of any of the preceding claims

wherein the fields generated by each of the field generators have a different frequency, a different phase, or both a different frequency and a different phase.

8. The locating system of any of the preceding claims, wherein the field generated by each field generator has a different frequency.

9. The locating system of claim 8, wherein the frequencies of the field generators are each integer multiples of a given frequency.

10. The locating system of any of claims 7-9, wherein the signal processor cross-correlates the signals corresponding to the drive and sensor signals.

11. The locating system of claim 9, wherein the signal processor cross-correlates the signals corresponding to the drive and sensor signals and wherein the duration of the cross-correlation of the inputs is the minimal common product of the integer multipliers divided by the given frequency.

12. The locating system of claim 10 or claim 11, wherein the results of the cross-correlation are used to calculate the contribution of each field generator to the signal generated by each said sensor.

13. The locating system of any of the preceding claims wherein the fields are AC magnetic fields.

14. The locating system of claim 13, wherein the AC magnetic fields are continuous fields.

15. The locating system of any of the preceding claims and including a display system for displaying the position of

the point on the invasive medical instrument.

16. The locating system of any of the preceding claims wherein there is an additional sensor on a portion of the invasive medical instrument which senses a local condition.

17. The locating system of claim 16 wherein the additional sensor senses local electrical signals and transfers them to terminals external to the patient's body.

18. The locating system of claim 17, wherein the signals are electrical signals from the endocardium of the patient's heart.

19. The locating system of claim 18, wherein the signal processor processes the position and orientation coordinate signals and the local electrical signals acquired at a plurality of points on the endocardium to generate a map that represents the propagation of electrical signals through tissue in the patient's body.

20. The locating system of any of claims 16-22 wherein the additional sensor is operative for supplying electrical energy to the endocardium for ablating a portion of the endocardium.

21. The locating system of any of claims 1-16 and including an electrode adapted for supplying electrical energy to the endocardium for ablating a portion of the endocardium.

22. The locating system of claim 16 wherein the additional sensor is an ultrasonic transmitter/receiver.

23. The locating system of claim 22 wherein the ultrasonic transmitter/receiver provides a less than three dimensional representation of the acoustic properties of tissue beyond

the distal end.

24. The locating system according to claim 23 wherein the distal end is deflectable.

25. The locating system according to claim 24 and including image reconstruction circuitry which receives a plurality of said less than three dimensional representations acquired at different orientations of the distal end and produces a three dimensional map of the acoustic properties of tissue at least partially surrounding the distal end.

26. The locating system of any of the preceding claims and further comprising a reference instrument which includes a plurality of sensors situated in the reference instrument, wherein said display system displays the position of the point on the invasive medical instrument relative to the position of a point on the reference instrument.

27. The locating system of claim 26, wherein the locating system comprises only a single reference instrument.

28. The locating system of claim 26 or claim 27 wherein the reference instrument is an invasive medical instrument and wherein said sensors are situated proximate the distal end thereof.

29. An imaging system for intra-body ultrasonic imaging comprising:

a invasive medical instrument having an axial-looking ultrasonic imaging transducer attached to a distal end of the instrument, which transducer generates a representation of the acoustic properties of tissue beyond the distal end;

means for manipulating the distal end to change the orientation thereof; and

image reconstruction circuitry which receives a

plurality of said representations acquired at different orientations of the distal end and produces a three dimensional map of the acoustic properties of tissue at least partially surrounding the distal end based on said plurality of representations acquired at different orientations of the distal end.

30. The imaging system of claim 29 and further comprising:

a plurality of field generators which generate known, distinguishable fields in response to drive signals;

a plurality of sensors situated in the invasive medical instrument proximate the distal end thereof which generate sensor signals in response to said fields; and

a signal processor which has an input for a plurality of signals corresponding to said drive signals and said sensor signals and which produces three location coordinates and three orientation coordinates of the a point on the transducer.

31. The imaging system of claim 29 or claim 30 wherein said representations are one or two dimensional representation.

32. The system of any of the preceding claims wherein the invasive medical instrument is a catheter or endoscope.

33. A method of determining the position and orientation of an invasive medical instrument having a distal end, comprising:

(a) generating a plurality of distinguishable, geometrically different AC magnetic fields;

(b) sensing the AC magnetic fields at a plurality of sensors proximate the distal end; and

(c) computing six dimensions of position and orientation of a portion of the invasive medical instrument responsive to signals representative of the generated magnetic fields and the sensed magnetic fields.

34. A method according to claim 33 wherein the plurality of distinguishable, geometrically different fields comprises three such fields.

35. A method according to claim 33 or claim 34 wherein the AC magnetic field is sensed at three points of the invasive medical instrument.

36. A method according to any of claims 33-35 wherein the invasive medical instrument is a catheter or endoscope.

37. An ultrasonic intra-body imaging method comprising:

(a) inserting an ultrasonic transducer into the body, said ultrasonic transducer producing a representation of the acoustic properties of tissue beyond an end of the transducer;

(b) manipulating the orientation of the transducer to provide a plurality of said representations;

(c) determining the six dimensions of position and orientation of the transducer for each of the representations; and

(d) constructing a three dimensional map of the acoustic properties of the tissue in a region at least partially surrounding the end of the transducer from said plurality of representations.

38. A method according to claim 37 wherein:

inserting a transducer comprises inserting an invasive medical instrument into the body of a patient, said ultrasonic transducer being positionally and orientationally fixed with respect to a distal end of the instrument; and

manipulating comprises changing the orientation of the distal end.

39. A method according to claim 37 wherein the

representation is a less than three dimensional representation.

40. A invasive medical instrument comprising a plurality of at least three magnetic field sensors proximate the distal end thereof, said sensors having a fixed orientation therebetween.

41. The instrument of claim 40 wherein each sensor comprises a coil.

42. The instrument of claim 41 wherein said plurality of coils have axes which intersect within a coil.

43. The instrument of any of claims 40-42 wherein the plurality is three.

44. The instrument of claim 41 or claim 42 wherein said plurality of coils comprises three coils and wherein said three coils have axes which do not all intersect in a point.

45. The instrument of any of claims 40-44 and further comprising an ultrasound transducer at said distal end.

46. The instrument of claim 45 wherein said ultrasound transducer provides a representation of the acoustic properties of tissue beyond and along the axis of the catheter.

47. The instrument of claim 46 wherein said representation is a one dimensional representation.

48. The instrument of claim 46 wherein said representation is a two dimensional representation.

49. The instrument of any of claims 40-44 and further

comprising an electrical probe at said distal end.

50. The instrument of claim 49 wherein said electrical probe is adapted to sense electrical signals generated by tissue which is in contact and conduct said signals to the proximal end of the catheter.

51. The instrument of claim 49 or claim 50 wherein said electrical probe is adapted to supply an ablative electrical signal to tissue contacting said probe.

52. The instrument of any of claims 40-44 and including a sensor for measuring local chemistry at the distal end.

53. The instrument of any of claims 40-52 wherein said instrument is a catheter or endoscope.

54. The instrument of any of claims 40-53 and also including means for changing the orientation of the distal end.

55. The instrument of claim 54 wherein the means for changing the orientation comprises;

a relatively more flexible wire passing through the medical instrument that is attached to the distal end and has a bend near the distal end;

a relatively more rigid sleeve which is straight near the distal end and which slideably holds the wire thereat, whereby when the sleeve is slid over the wire, the wire and distal end are straightened.

56. An instrument according to claim 55 wherein instrument has a lengthwise axis and wherein the wire is sited off the axis of the instrument.

57. An instrument according to claim 54 wherein the means

for changing the orientation comprises;

a flat relatively flexible portion being slit along a portion of the length thereof to form two portions which are attached at a first end thereof, said first end being attached to the distal end of the instrument;

a pair of wires, one end of each of which being attached to one of said portions at a second end thereof; and

means for changing the relative lengths of the wires whereby the flexible element is bent, thereby steering the distal end of the instrument.

58. Apparatus for steering the distal end of an invasive medical instrument comprising:

a flat relatively flexible portion being slit along a portion of the length thereof to form two portions which are attached at a first end thereof, said first end being attached to the distal end of the instrument;

a pair of wires, one end of each of which being attached to one of said portions at a second end thereof; and

means for changing the relative lengths of the wires whereby the flexible element is bent, thereby steering the distal end of the instrument.

59. Apparatus according to claim 58 wherein the invasive medical instrument is a catheter or endoscope.

60. A method of producing a three dimensional image of the internal surface of an internal body organ comprising:

measuring the distance to said surface from a plurality of orientations and positions within the internal surface; and

assembling the distance measurements to form an image of the surface.

61. A method according to claim 60 wherein the measurement of distances is preformed utilizing an ultrasonic transducer.

62. A invasive medical instrument comprising a plurality of magnetic field sensors and an ultrasound transducer proximate the distal end thereof.

63. The instrument of claim 62 wherein said ultrasound transducer provides a representation of the acoustic properties of tissue beyond and along the axis of the catheter.

64. The instrument of claim 63 wherein said representation is a one dimensional representation.

65. The instrument of claim 63 wherein said representation is a two dimensional representation.

66. The instrument of any of claims 45-48 and 62-65 wherein the ultrasound transducer is positionally and orientationally fixed with respect to the distal end of the instrument.

67. The instrument of claim 66 and including means for controlably changing the orientation of the transducer by changing the orientation of the distal end of the instrument.

68. The instrument of any of claims 62-67 wherein said instrument is a catheter or endoscope.

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